

Calculation of the number and type of neutrino interactions for each period and each emulsion module

- In order to compare DATA and MC we need to simulate data as accurately as possible.
- Also in order to construct the ANN's that will perform classification on neutrino interactions we need to simulate the data set on which we are going to use the NN as accurately as possible.
- For that we calculate the number and type of neutrino interactions that we expect per period and per emulsion module (with no errors computed for the moment).

Expected number of neutrino interactions per run period and per emulsion module (relations)

- Number of neutrino interactions $Y = \frac{N(v)}{POT} \cdot (POT) \cdot P_{int.}$
where $N(v)/POT$ = number of neutrinos per proton on target

$P_{int.}$ = probability of interaction

POT = number of protons on target

$$P_{int.} = \frac{(\sigma(cm^2) \cdot A) \cdot N_A(atoms/mole) \cdot \rho(gr/cm^3) \cdot L(cm) \cdot \beta}{A(gr/mole)}$$

where β = acceptance (probability of a neutrino passing through the emulsion target and $\beta = 0.064$).

$$\frac{N(v_{\mu(e)})}{POT} = \frac{N(v_{\mu(e)})}{D^+} \cdot \frac{N(D^+)}{N(p)} + \frac{N(v_{\mu(e)})}{D^-} \cdot \frac{N(D^-)}{N(p)} + \frac{N(v_{\mu(e)})}{D^0} \cdot \frac{N(D^0)}{N(p)}$$

$$\frac{N(v_{\mu(e)})}{D^{+-0}} = BR(D^{+-0} \rightarrow \mu(e) + \text{anything})$$

$$\frac{N(D^{+-0})}{N(p)} = \frac{A \cdot \sigma(pN \rightarrow D^{+-0} X)}{A^{0.69} \cdot \sigma(pN)}$$

Expected number of neutrino interactions per run period and per emulsion module (relations -values)

- For tau neutrinos:

$$\frac{N(v_\tau)}{POT} = \frac{N(v_\tau)}{D_s} \cdot \frac{N(D_s)}{N(p)}$$

$$\frac{N(v_\tau)}{D_s} = 2 \cdot BR(D_s \rightarrow \tau + v_\tau)$$

$$\frac{N(D_s)}{N(p)} = \frac{N(D_s)}{N(D^+)} \cdot \frac{N(D^+)}{N(p)} = \frac{\sigma(pN \rightarrow D_s X)}{\sigma(pN \rightarrow D^+ N)} \cdot \frac{A \cdot \sigma(pN \rightarrow D^+ N)}{A^{0.69} \cdot \sigma(pN)}$$

VALUES FOR THE VARIOUS ELEMENTS :

$$\sigma_{v_\mu(v_e)}^{CC} = 6.34 \cdot 10^{-39} \text{ cm}^2 / \text{GeV}$$

$$\frac{\sigma_{v_\nu}^{NC}}{\sigma_{v_\nu}^{CC}} = 0.31$$

$$\langle E_{v_\mu} \rangle = 54 \text{ GeV}$$

$$\sigma_{\bar{v}_\mu(\bar{v}_e)}^{CC} = 3.15 \cdot 10^{-39} \text{ cm}^2 / \text{GeV}$$

$$\langle E_{v_e} \rangle = 54 \text{ GeV}$$

$$\sigma_{v_\tau}^{CC} = 0.666 \cdot 6.34 \cdot 10^{-39} \text{ cm}^2 / \text{GeV}$$

$$\frac{\sigma_{\bar{v}_\tau}^{NC}}{\sigma_{\bar{v}_\tau}^{CC}} = 0.38$$

$$\langle E_{v_\tau} \rangle = 90 \text{ GeV}$$

$$\sigma_{\bar{v}_\tau}^{CC} = 0.666 \cdot 3.15 \cdot 10^{-39} \text{ cm}^2 / \text{GeV}$$

$$\sigma(pN) = 34 \text{ mb} \quad \sigma(D^{+-}) = 25 \mu\text{b} \quad A_{\text{arg.}} = 181.28$$

$$\frac{\sigma(D_s X)}{\sigma(D^+ N)} = 0.5$$

$$BR(D^{+-} \rightarrow \mu(e)^{+-} + \text{anything}) \approx 17\%$$

$$BR(D_s \rightarrow \tau + v_\tau) \approx 7\%$$

$$BR(D^0 \rightarrow \mu(e)^{+-} + \text{anything}) \approx 6.6(6.75)\%$$

Expected number of neutrino interactions per run period and per emulsion module (values 2)

VALUES FOR THE VARIOUS ELEMENTS :

$$L = 6\text{cm}$$

$$\rho_{\text{BULK}} = 3.8\text{gr/cm}^3$$

$$A_{\text{BULK}} = 26.64\text{gr/mole}$$

Since ECC = 95% Steel + 0.05% Emulsion

$$\rho_{\text{ECC}} = 0.95(0.98 \cdot 56 + 0.02 \cdot 12) + 0.05 \cdot (26.64) = 7.6\text{gr/cm}^3 \quad A_{\text{ECC}} = 53.7\text{gr/mole}$$

Since E/B4 = 57% ECC + 43% Bulk

$$\rho_{\text{E/B4}} = 6.0\text{gr/cm}^3$$

$$A_{\text{E/B4}} = 42.9\text{gr/mole}$$

Since E/B3 = 68% ECC + 32% Bulk

$$\rho_{\text{E/B3}} = 6.5\text{gr/cm}^3$$

$$A_{\text{E/B3}} = 46\text{gr/mole}$$

Since E/B2 = 61% ECC + 39% Bulk

$$\rho_{\text{E/B2}} = 6.2\text{gr/cm}^3$$

$$A_{\text{E/B2}} = 44\text{gr/mole}$$

Since E/B1 = 72% ECC + 28% Bulk

$$\rho_{\text{E/B1}} = 6.6\text{gr/cm}^3$$

$$A_{\text{E/B1}} = 47.2\text{gr/mole}$$

Expected number of neutrino interactions per run period and per emulsion module (results - values)

- Number of neutrinos per proton on target :

$$\left. \begin{array}{l} \frac{N(\nu_\mu \text{prompt})}{\text{POT}} = 1.49 \cdot 10^{-3} \\ \\ \frac{\text{prompt}}{\text{prompt} + \text{non-prompt}} = 0.78 \end{array} \right\} \quad \begin{array}{l} \frac{N(\nu_\mu \text{non-prompt})}{\text{POT}} = 0.42 \cdot 10^{-3} \end{array}$$

$$\frac{N(\nu_\tau)}{\text{POT}} = 2.58 \cdot 10^{-4}$$

$$\frac{N(\nu_e)}{\text{POT}} = 1.5 \cdot 10^{-3}$$

	PERIOD1	PERIOD2	PERIOD3	PERIOD4
POT	5.39x10¹⁶	4.38x10¹⁶	1.03x10¹⁷	1.55x10¹⁷

Expected number of neutrino interactions per run period and per emulsion module

PERIOD-1	ECC	0	ECC	0	Tot.
$v_{\mu} \text{ CC}$	46.36		46.36	92.72	38.60%
$v_e \text{ CC}$	36.40		36.40	72.80	30.33%
$v_{\tau} \text{ CC}$	7.26		7.26	14.52	6.05%
NC	29.99		29.99	59.98	25.00%
Tot.	120.01		120.01	240.02	
PERIOD-2	ECC	0	ECC	E/B4	Tot.
$v_{\mu} \text{ CC}$	37.68		37.68	29.74	105.10
$v_e \text{ CC}$	29.58		29.58	23.35	82.51
$v_{\tau} \text{ CC}$	5.5		5.5	3.75	14.75
NC	24.23		24.23	18.95	67.41
Tot.	96.99		96.99	75.79	269.77

Expected number of neutrino interactions per run period and per emulsion module.

PERIOD-3	ECC	E/B2	E/B3	E/B4	Tot.	
v_μ CC	88.59	72.28	75.77	69.95	306.59	39.24%
v_e CC	69.57	56.76	59.50	54.92	240.75	30.82%
v_τ CC	11.17	9.10	9.55	8.82	38.64	4.95%
NC	56.42	46.03	48.25	44.54	195.24	24.99%
Tot.	225.75	184.17	193.07	178.23	781.22	

PERIOD-4	E/B1	E/B2	E/B3	B4	Tot.	
v_μ CC	133.32	125.24	131.30	75.35	465.21	39.23%
v_e CC	104.59	98.36	103.12	59.17	365.24	30.81%
v_τ CC	17.08	15.79	16.56	9.5	58.93	4.97%
NC	84.97	79.78	83.63	47.97	296.35	24.99%
Tot.	339.96	319.17	334.61	191.99	1185.73	

Results

- From all the above numbers we get for each period :

$$\begin{array}{lll} v_{\mu CC} \sim 40 \% & \text{if we consider trigger efficiency} & 41.0 \% \\ v_{e CC} \sim 30 \% & 93\% v_{\mu CC} - 97\% v_{e CC} & 31.6 \% \\ v_{\tau CC} \sim 5 \% & 95\% v_{\tau CC} & 5.2 \% \\ NC \sim 25 \% & 86\% NC & 23.2 \% \end{array}$$

- The neutrino beam consists of $\sim 7\% v_{\tau} \quad 41\% v_e \quad 52\% v_{\mu}$

- The ratio of events for each period :

period1 9.7 % period2 10.9% period3 31.5% period4 47.9%

- The ratio of events for each module of each period:

period 1 50% 0 50 % 0

period 2 36% 0 36% 28%

period 3 29% 24% 25% 22%

period 4 29% 27% 28% 16%

Results compared with Data (886 cat3)

- The ratio of events for each period :

expected :

period1 9.7 % period2 10.9% period3 31.5% period4 47.9%

observed:

period1 10.8 % period2 8.8 % period3 34.4 % period4 46.0 %

These numbers do not differ significantly

- The ratio of events for each module of each period for periods 3 and 4:

expected :

period 3 29% 24% 25% 22%

observed:

period 3 31.25% 18.42% 19.41% 30.92%

expected :

period 4 29% 27% 28% 16%

observed:

period 4 27.75% 25.50% 21.75% 25.00%

For both periods the events on module 1 are about the same.

There seems to be an excess of events in module 4 and a deficit of events in module 2 and 3 .

Values for ANN and MC DATA comparison

- If the previous calculations are correct then for MC - DATA comparison we can use:

$$v_{\mu CC} \sim 40\% \quad v_e CC \sim 30\% \quad \text{prompt/prompt+non-prompt}=0.78$$

$$v_{\tau CC} \sim 5\% \quad NC \sim 25\% \quad 7\% v_{\tau} \quad 41\% v_e \quad 52\% v_{\mu}$$

(for ANN construction these numbers are not important since in all cases we train our NN with equal numbers of “signal” and “background” events.)

- For the percentage of neutrino interactions per period for ANN construction for the 203 events the values we get from data are different than the expected (if that is an unbiased set). It might be better to use the observed rather than the expected values.

expected :

period1 **9.7 %** period2 **10.9%** period3 **31.5%** period4 **47.9%**

observed:

period1 **13.7 %** period2 **9.3 %** period3 **22.4 %** period4 **54.6 %**

- For the percentage of neutrino interactions per emulsion module both for MC-DATA comparison and ANN construction which of the two numbers is better to use ?